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16. ABSTRACT The paper discusses the application of catalytic oxidation to four types of air emission sources: (1) groundwater stripping operations, (2) graphic arts facilities, (3) flexographic printing plants, and (4) latex monomer production. Characteristics of each of these emissions are discussed, along with the catalytic technology used to control them. In addition to key emission stream characteristics, the paper discusses hazardous air pollutant characteristics that affect the applicability of catalytic oxidation.

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Destruction of Volatile Organic Compounds Using Catalytic Oxidation

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Catalytic oxidation is an air pollution control technique in which volatile organic compounds (VOCs) and vapor-phase air toxics in an air emission stream are oxidized with the help of a catalyst. Design of catalytic systems for control of point source emissions is based on stream-specific characteristics and desired control efficiency. This paper discusses the key emission stream characteristics and VOC characteristics that affect the applicability of catalytic oxidation. The application of catalytic oxidation technology to four types of air emission sources is discussed: (1) groundwater stripping operations; (2) graphic arts facilities; (3) flexographic printing plants; and (4) latex monomer production. The characteristics of each of these emissions are discussed along with the catalytic technology used to control these emissions.

The most frequent approach to point source air emissions control is the application of add-on control devices. For organic vapors, these devices can be of two types: combustion and recovery. Applicable combustion devices include thermal incinerators, catalytic incinerators, flares, and boilers/process heaters. Applicable recovery devices include condensers, adsorbers, and absorbers. The combustion devices are the more commonly applied control devices, since they are capable of high removal (destruction) efficiencies for almost any type of volatile organic compound (VOC). The removal efficiencies of the recovery techniques generally depend on the physical and chemical characteristics of the VOC under consideration.

Applicability of the control techniques depends more on the individual emission stream under consideration than on the particular source category of the emissions. Thus, applicable control techniques for point source emissions are selected on the basis of stream-specific characteristics and desired control efficiency. The key emission stream and VOC characteristics that affect the applicability of each control technique are: VOC content, heat content, moisture content, flow rate, temperature, and molecular weight.

Matching the characteristics of the stream under consideration with the useful ranges of the control devices will help the user to identify those techniques that can potentially be used to control the emission stream. Catalytic oxidation, for example, is generally useful for concentrations of 50 to 10,000 ppmv, if the total concentration is less than 25 percent of the lower explosive limit (LEL), and for flow rates of less than 100,000 scfm (170,000 Nm^3/h). The list of potential applicable control techniques can then be narrowed further depending on the capability of the applicable control devices to achieve the required performance levels. For example, catalytic incineration can achieve an expected control efficiency of greater than 95 percent at total VOC concentrations of greater than 100 ppmv.[1]

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Catalytic Oxidation Technology

The topic of this presentation is catalytic incineration, which is also called catalytic oxidation or destruction. Catalytic incineration is an air pollution control technique whereby VOCs and vapor-phase organic air toxics in an air emission stream are oxidized with the help of a catalyst. Catalysts typically used for VOC incineration include platinum and palladium. Other formulations are also used, including metal oxides for emissions streams containing chlorinated compounds.

A typical catalytic oxidation system with primary and secondary heat recovery is shown in Figure 1. Process air emissions, generally at ambient temperatures, are passed through the primary heat exchanger to recover heat from hot exhaust gases. If necessary, the emission stream is then preheated to catalytic oxidation temperatures in a natural-gas-fired, or electric preheater before passing into the catalyst bed. A small portion of the process air emissions is separated from the controlled stream and used as combustion air.

The catalyst bed (or matrix) is generally a metal-mesh mat, ceramic honeycomb, or other ceramic matrix structure designed to maximize catalyst surface area. Catalysts may also be in the form of spheres or pellets which may operate in either a fixed or a fluidized bed configuration. Care must be taken that high preheat temperatures accompanied by the increase in temperature due to combustion do not result in high operating temperatures in the catalyst bed. This could cause the catalyst bed to overheat and eventually lose its activity.

Exhaust gases then pass through the not side of the primary heat exchanger, giving up heat to the inlet stream. If the economics are favorable, secondary heat recovery is used. Recovered heat is

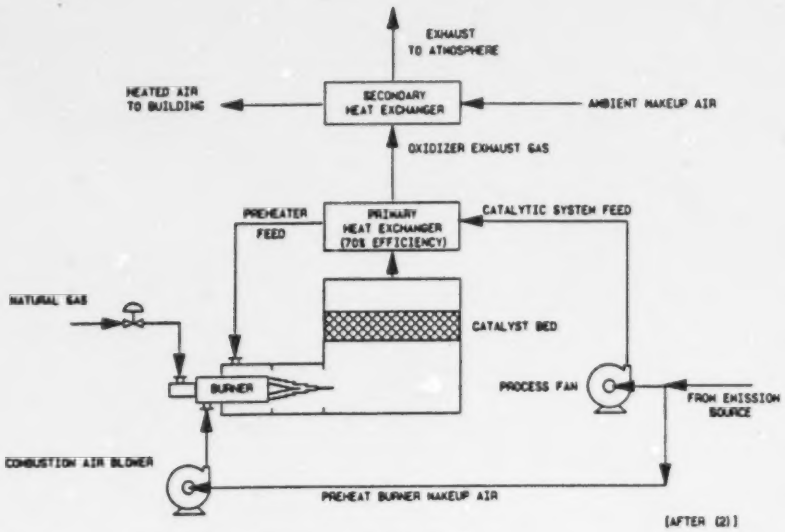

Figure 1. Process flow sketch—catalytic oxidation system.

often used for process heat or, in the case of printing operations, for dryer makeup air preheating. If the oxidized streams contain chlorinated compounds, caustic scrubbing may be required before the exhaust stream can be emitted to the atmosphere.

The performance of a catalytic incinerator is affected by several factors including: (1) operating temperature; (2) space velocity (reciprocal of residence time); (3) VOC composition and concentration; (4) catalyst properties; and (5) presence of poisons/inhibitors in the emission stream. In catalytic incinerator design, the important variables are the operating temperature at the catalyst bed inlet and the space velocity. The operating temperature for a particular destruction efficiency is dependent on the concentration and composition of the VOC in the emission stream and the type of catalyst used.

Space velocity is defined as the volumetric flow rate of the combined gas stream (i.e., emission stream + supplemental fuel + combustion air) entering the catalyst bed divided by the volume of the catalyst bed. As such, space velocity also depends on the type of catalyst used. At a given space velocity, increasing the operating temperature at the inlet of the catalyst bed increases the destruction efficiency. At a given operating temperature, as space velocity is decreased (i.e., as residence time in the catalyst bed increases), destruction efficiency increases. Catalytic incinerators can achieve overall VOC destruction efficiencies up to about 98 percent and individual compound destruction efficiencies up to about 95 percent with space velocities in the range 30,000 to 100,000 gas hourly space velocity (GHSV).[3-5] However, the greater catalyst volumes and/or higher temperatures required for high destruction efficiencies (e.g., 99 percent) may make catalytic incineration uneconomical.

The performance of catalytic incinerators is sensitive to pollutant characteristics and process conditions. Therefore, in these introductory discussions, it is assumed that the emission stream is free from poisons/inhibitors such as phosphorus, lead, bismuth, arsenic, antimony, mercury, iron oxide, tin, zinc, sulfur, and halogens. It is also assumed that the fluctuations in process conditions (e.g., changes in VOC content) are kept to a minimum as are liquid or solid particles that could deposit on the catalyst and form a coating, thereby reducing the catalyst's activity. Additionally, catalyst life is limited by thermal aging and by loss of active sites by erosion, attrition, and vaporization. With proper operating temperatures and adequate temperature control, these deterioration processes are normally slow, and satisfactory performance can be maintained for three to five years before replacement of the catalyst is necessary.

Table I presents suggested values and limits for the design variables of a fixed bed catalytic incinerator system to achieve a given destruction efficiency. For specific applications, other temperatures and space velocities may be appropriate depending on the type of catalyst employed and the emission stream characteristics (i.e., composition and concentration). For example, the temperature of the flue gas leaving the catalyst bed may be lower than 1,000°F (538°C) for emission streams containing easily oxidized compounds and still achieve the desired destruction efficiency. Note that the destruction efficiency for a given compound may vary depending on whether the compound is the only VOC in the emission stream, or is part of a mixture of VOCs.[3]

Supplementary fuel is added to the catalytic incinerator system to provide the heat necessary to bring the emission stream up to the required catalytic oxidation temperature for the desired level of destruction efficiency. For a given inlet temperature, the quantity of supplementary heat needed is provided by: (1) the heat supplied from the combustion of supplementary fuel; (2) the sensible heat contained in the emission stream as it enters the catalytic incinerator system; and (3) the sensible heat gained by the emission stream through heat exchange with hot flue gases. If recuperative heat exchange is not practiced at a facility, then item (3) will be zero.

Case Study 1: Air Stripping of Groundwater

Air stripping of groundwater has been shown to be an efficient and cost effective method of removing VOCs from groundwater and soil. The removal of dissolved fuel fractions and chlorinated solvents at efficiencies in excess of 95 percent has been demonstrated on several occasions. Unfortunately, these contaminants are transferred to the air where they may continue to pose environmental and health threats. Regulation of such emissions has already been considered in many states, including Michigan and California.

The applicability of catalytic oxidation to the control of groundwater stripping gaseous emissions will be reviewed with special attention given to system designs and case histories. The

Table I. Catalytic incineration system design variables.[4-6]

Required destruction efficiency (%)	Minimum temperature at catalyst bed inlet [°F (°C)]	Temperature at catalyst bed outlet (minimum–maximum) [°F (°C)]	Space velocity (h^{-1})
90	600 (316)	1,000–1,200 (538–649)	40,000
95	600 (316)	1,000–1,200 (538–649)	30,000

variety of contaminants and catalyst poisons encountered in stripping operations will also be reviewed. Presently, few options are available for the control of groundwater air stripping emissions. Vapor-phase carbon adsorption and thermal incineration are the two treatment methods which are best established. These technologies have some disadvantages. Adsorption merely transfers the contaminant to a solid phase, which in turn requires disposal or regeneration. Regeneration with steam results in a contaminated waste water stream which requires treatment and disposal. Thermal incineration may be expensive, since it requires a substantial energy input to destroy dilute gas-phase contaminants. Catalytic oxidation is establishing itself as a new alternative to these more established technologies. Like thermal incineration, it is an ultimate disposal method, but since it operates at much lower temperatures, the energy costs are also lower.

A hypothetical system with catalytic destruction of air stripping effluents is pictured in Figure 2.[7] Air is countercurrently contacted with a contaminated water stream. Most volatile compounds are transferred to the air stream, and the water receives a final cleanup in the liquid polishing step before disposal. The catalytic destruction of organic emissions in the air stream differs from other catalytic pollution control applications in several important aspects. First, the concentration of the contaminants in the gas phase is quite low, in most cases less than 100 ppmv. Second, the humidity levels are unusually high since the air stream is saturated coming off the stripping unit. Third, a wide variety of contaminants and mixtures (ranging from chlorinated compounds and soluble fuel fractions to pesticides and polychlorinated biphenyls) may be in any groundwater source. Finally, the air stream exiting a groundwater stripper may have high concentrations of mineral aerosols and catalyst poisons (e.g., hydrogen sulfide) that will shorten catalyst life. All of these factors make the design and implementation of catalytic treatment uncertain.

Table II. Typical organic concentrations in air stripping overhead.[8]

Compound	Concentration in gas phase (ppmv)[a]
Pentane	42.4
Cyclohexane	66.1
Methyl cyclopentane	7.7
2,3-Dimethyl butane	1.6
Trichloroethylene	17.9
Benzene	9.2
Ethyl benzene	8.3
Cumene	3.4
Mixed xylenes	21.3
Total	177.9

[a] Calculated at a gas/liquid ratio of 42/1 for 1-in. (2.5-cm) Pall rings.

The emissions from air stripping units may consist of a complex mixture of reactants including both fuel and solvent fractions. A typical example of an air stripping off-gas stream is shown in Table II. This table lists the concentration of selected contaminants emitted from a pilot stripping unit at Wurtsmith Air Force Base in Michigan.[8] Here, no individual contaminant exceeds 70 ppmv, but the cumulative total exceeds 170 ppmv.

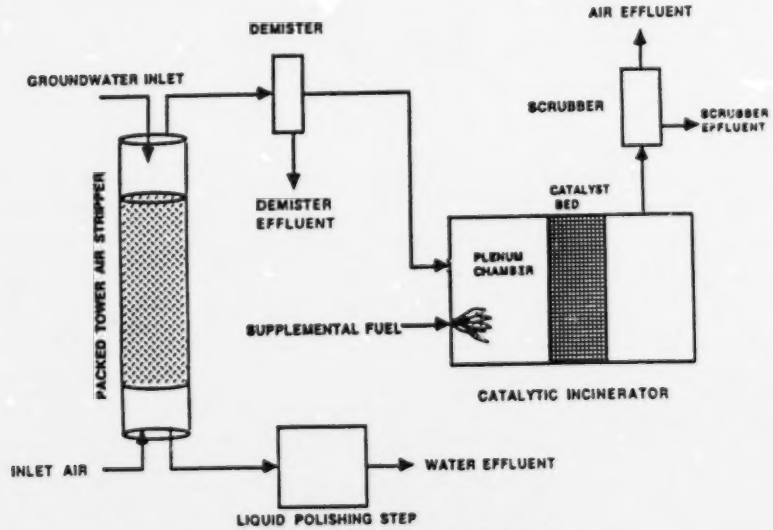

Figure 2. System configuration for catalytic destruction of air stripping emissions.

The energy burden of heating a cold, water-laden air stripping effluent stream should be lower for a catalyst system than for thermal incineration, but it still represents a considerable operating cost. The air from most air stripping units can be considered to be saturated with water. This corresponds to an absolute water vapor concentration of between 0.8 and 3.1 percent in the exit stream. The action of bubbles in the stripping unit also produces a large amount of liquid aerosol. The carryover of liquid water in the form of small droplets and aerosol represents an additional large heat burden on any catalyst bed and should be minimized by the use of demisters or filters if possible. Aerosol removal has an additional advantage, in that mineral or biological matter which might foul and deactivate the catalyst bed is also removed.

The high concentration of water vapor in the emission stream represents a major difference between this application of catalytic control and other more typical applications. As of now, no firm basis exists to predict the behavior of non-halogenated hydrocarbon oxidation in the presence of water. On the other hand, the effect of water on the catalytic destruction of chlorinated compounds is generally thought to be beneficial. The most easily treated products of this process are hydrochloric acid (HCl), carbon dioxide (CO_2), and water; however, some solvents such as trichloroethylene (C_2HCl_3) do not have stoichiometric amounts of hydrogen to allow complete reaction of the chlorine to HCl. For those compounds, water may serve as this hydrogen source, or may merely favorably alter the reaction thermodynamics. Other hydrogen sources such as methane or propane may also be beneficial in promoting HCl formation. As with the non-halogenated hydrocarbons, a clearer understanding of the catalytic chemistry is essential to understanding the role of water vapor.

As a further complication, many contaminated groundwater sources may contain mixtures of hydrocarbons and halogenated compounds. Laboratory and pilot studies have found significant mixture effects for oxidation of hydrocarbons, chiefly in the form of inhibition.[9,10] This means that the catalytic oxidation of a given compound is generally negatively impacted by the presence of mixtures, and higher catalyst bed operating temperatures may be necessary to achieve adequate destruction. Information on mixture effects for halogenated compounds is extremely limited.

Catalysts exposed to the air stripping effluent are subject to deactivation from several sources: fouling, thermal degradation, poisoning, and catalyst volatilization. The catalyst bed

may plug or become encrusted, thereby losing its effectiveness due to dissolved salts and mineral matter in the air stripping off-gases. As mentioned previously, removal of aerosols prior to the catalyst unit may alleviate this problem. If the catalyst bed is operated at high temperatures [greater than 1,110°F (600°C)] for prolonged periods, sintering of active noble metals may occur, also resulting in loss of activity. Groundwater also often contains significant amounts of readily strippable compounds, such as hydrogen sulfide (H_2S), that may poison the catalyst surface by adsorbing and blocking active sites. Higher operating temperatures may remove some of these poisons, but sintering may then become a problem. Finally, some reactants, especially halogenated compounds, may chemically bond with the active catalyst and subsequently volatilize from the surface. The loss of catalyst associated with this vaporization process inevitably results in lower catalyst efficiency.

A recent EPA report[11] identified 177 air strippers in the United States. Of these, 17 are equipped with air emission controls. Of the 17 facilities; one uses a catalytic incinerator, two have open flares, two have thermal incinerators, and 12 have granular activated carbon adsorbers. The identified catalytic incinerator is located at the U.S. Coast Guard Base in Traverse City, Michigan. This air stripper system began operation in 1985. The catalytic incinerator was included in the initial design and installation of the air stripping system. The stripper installed at this site is a rotary high-gravity stripper which achieves high removal efficiencies at lower air to water ratios than packed towers. The lower air flow for this type of stripper results in higher pollutant concentrations in the stripper exhaust.

The catalytic incinerator at Traverse City was installed for destruction of benzene, toluene, and xylene stripped from the groundwater. The catalytic oxidation unit is designed for a flow of 2,000 scfm (3,400 Nm^3/h) and operates at 500 to 600°F (260 to 320°C). The design efficiency for this catalytic incinerator was 90 percent. The estimated installed cost for the catalytic unit is $198,500, and annual operating costs for the 2,000 scfm unit are $95,920 (based on third quarter 1986 data).[11]

Case Study 2: Graphic Arts

Dryer emissions from the graphic arts (heat-set web offset printing) industry are primarily composed of hydrocarbon solvent, alcohol (if used), water vapor, and the byproducts of burner combustion (CO_2 and traces of unburned natural gas). Eventually all of these materials are exhausted from the dryer, resulting in three pollution problems which need to be addressed: "smoke" or opacity, odor, and VOCs. The smoke observed is actually condensing ink solvents and water vapor. The odor is a function of the solvents and resins used. The organic compounds are the hydrocarbon solvents, alcohol, and unburned natural gas. A pollution control device must deal with all three of these problems to be effective.

Typical ink solvents used in the web offset industry are petroleum fractions distilled from crude oil and are similar to No. 2 fuel oil. These solvents typically boil in the range of 440 to 600°F (225 to 315°C) and are generally composed of approximately 85 percent aliphatic, 10 percent aromatic, and 5 percent olefinic hydrocarbons. Carbon numbers range from C9 to approximately C20 with the largest concentration in the area of C14. A typical molecular weight for these solvents is 210, and they typically have a net heating value of 19,950 Btu/lb (11,080 kcal/kg). The lower explosive limit (LEL) for a solvent of this type is approximately 0.455 percent by volume at 300°F (150°C).[12]

A second component of web offset dryer exhaust is often isopropyl alcohol. Used in the fountain solution, this very volatile material is carried with the web into the dryer where almost all is evaporated. It is very difficult to measure the alcohol which does reach the dryer because a percentage of the alcohol escapes into the pressroom as fugitive emissions. Recent advances in the use of less volatile alcohol substitutes have greatly reduced the volume of alcohol used by printing plants.

One option for control of web offset emissions is catalytic incineration. Catalytic incinerators can be configured in the same manner as thermal incinerators with the use of primary heat exchangers to preheat the solvent-laden exhaust to the temperature necessary for catalytic oxidation. In addition, a secondary heat exchanger can be added, as in Figure 1, to provide heated makeup air to the dryer.

If, in the printing process, both the ink coverage is heavy enough and press speed is high enough, then the catalyst preheat burner may be able to shut off, allowing the unit to run with only the oxidation of ink solvent as a source of energy. This mode of operation presents the possibility for substantial energy savings. In addition, when heated makeup air is returned to the dryer, the need for fuel at the dryer is reduced. Alternatively, if the heated air is used to drive another recovery device (absorptive chiller, building heating and ventilating system, etc.), the auxiliary energy required to fuel that device would also be reduced.

Catalytic incineration does, however, suffer from a number of disadvantages in this application. Heat-up times are as long for catalytic units as for thermal units due to the large physical mass of catalyst which must be heated to the proper oxidation temperature. This disadvantage can be overcome to some extent. By incorporating an automatic damper, the system can be maintained in the "ready" mode with a minimum energy requirement. The cost of catalyst can be substantial, causing the initial capital investment for a catalytic system to be from 15 to 30 percent higher than for an equivalent thermal system. Catalyst life may vary from one to five years or more depending on the composition of the catalyst, as well as operating and process variables.[12]

In the graphic arts industry, the catalyst in catalytic incinerators should be monitored regularly because it is susceptible to contamination by phosphorus (phosphate buffers) from fountain solutions, silica from silicone gloss-enhancer sprays, or chlorides from chlorinated solvents or blanket wash solutions. The precious metal catalyst is not poisoned by sulfur, but base metal catalysts are rapidly deactivated by sulfur in this application.[13]

Phosphorus and silica accumulate most rapidly on the leading edge of the catalyst bed and deactivate the catalyst by masking the precious metals. Both phosphorus and silica bond to either the alumina substrate or alumina washcoat. Because of phosphorus and silica poisoning, TEC Systems, a major supplier (to the printing industry) of dryers and ancillary equipment including catalytic incinerators, has changed to bead type catalyst beds with low space velocities (about 7,000 to 8,000 GHSV).[13] With deeper catalyst beds, the leading edge of the catalyst tends to collect the poisons and thus protects the catalyst beads deeper in the bed. Catalyst beds with high space velocities (near 30,000 GHSV), such as monolith catalysts, often require frequent cleaning, sometimes as often as every three months.

Chloride poisoning is much less common than phosphorus or silica poisoning; however, since it reacts directly with the precious metals, chloride deactivates the catalyst at much lower concentrations. Three potential sources of chloride poisoning are fire extinguishing systems, refrigeration systems which utilize fluorocarbons such as trichlorotrifluoroethane, and chlorinated hydrocarbon solvents.[13]

In some cases, TEC Systems has found that a catalyst unit may fail a compliance test even though the catalyst is in good shape.[13] Failures of this nature have been traced to cracked heat exchangers, low catalyst levels, abnormally low incineration tempera-

tures, leaking bypass dampers, and erroneous test results.

Case History 3: Flexographic Printing Plant

A metal oxide catalyst in a fluidized bed configuration has been applied to a flexographic printing plant in Massachusetts.[2] In many ways, this use is similar to the graphic arts application discussed in Case 2. The exhaust fumes from 10 flexographic printing drying ovens containing 120 lb/h (55 kg/h) of VOCs, 5 lb/h (2.3 kg/h) of silicones, and trace amounts of chlorinated hydrocarbons are controlled using catalytic oxidation. However, since the catalyst surface is continually renewed by abrasion in the fluidized bed, the problem of masking the catalyst surface with silicones is avoided. The use of a metal oxide catalyst avoids the problem of chlorine poisoning.

The system was installed in October 1986. Operating conditions shown in Table III are typical of those used for easily combusted emissions. The vendor states that the tested efficiency was in excess of 99 percent. This high destruction efficiency is attributed to operation at 73 percent of design air flow rate. Decreased flow (hence decreased space velocity) increases destruction efficiency. The plant operates 24 h/day, 5 days/wk, and 260 days/yr. The incineration system also includes a 70-percent thermally efficient self-recuperative plate type heat exchanger for building heating. Design conditions are shown in Figure 3.

The cost of the catalytic incinerator (including the catalyst and process fan but not including the cost of heat exchangers) was $133,430. The annual operating cost for fuel is $14,071/yr at an energy cost of $5.00/10^6 Btu ($0.00002/kcal). This value does not include any credit for building heating costs which were cut by 50 percent. Catalyst costs are $5,377/yr.

Table III. Operating conditions for catalytic control of a flexographic printing plant.[2]

Air flow rate	11,000 scfm	18,700 Nm^3/h
(design value)	15,000 scfm	25,500 Nm^3/h
VOC loading	3 to 6% of LEL	
(fuel value)	1.5 to 3.1 Btu/scf	13 to 28 kcal/Nm^3
Bed inlet temperature	700°F	370°C
Bed outlet temperature	775 to 850°F	415 to 455°C
Catalyst pressure drop	10 in. water	18.7 mm Hg
Fuel consumption	0.451 × 10^6 Btu/h	114,000 kcal/h

The vendor also calculated costs for a thermal incinerator operating at 11,000 scfm (18,700 Nm^3/h) with the same heat recovery. Fuel costs were estimated at $159,931/yr at $5.00/10^6 Btu ($0.00002/kcal). The exit temperature of the incinerator was estimated as 1,400°F (760°C).[2]

Case Study 4: Latex Monomer Production

For many years, one of the accepted methods of oxidizing gaseous hydrocarbon emissions has been by thermal incineration. This became the obvious choice when dealing with carcinogenic chlorinated hydrocarbon emissions; however, with 2,200°F (1,200°C) oxidation temperatures and 2-s dwell times, incinerators became very large and the fuel costs excessive. The alternate choice was catalytic oxidation; however, the catalyst was easily poisoned and the unit became ineffective. ARI Technologies has introduced a catalyst system which they claim can complete the reaction at an average bed temperature of 700°F (370°C) while achieving conversion efficiencies in excess of 99.99 percent.[2]

One difficult application of chlorinated hydrocarbon emissions control is the manufacture of latex monomers. Being a typical batch operation, the concentration of chlorinated hydrocarbons varies widely from a heat content of 4 to over 300 Btu/scf (36 to 2,700 kcal/Nm^3), which results in a potential temperature rise across the catalyst of 200 to 1,500°F (95 to 815°C). During periods of very high concentrations, the temperature rise across the catalyst bed is kept within a reasonable range by the addition of dilution air.

At the present time, five plants are operating successfully using catalytic incineration as the control technology of choice. The range of operating parameters for a typical 4,000 scfm (6,800 Nm^3/h) catalytic incineration system is shown in Table IV. Note the wide range of dilution air rates needed to compensate for the heat content of the process gas and the need for caustic scrubbing for control of HCl emissions. The high conversion efficiency may be possible, if the chlorinated hydrocarbon is vinyl chloride, based on laboratory results which seem to indicate that vinyl chlo-

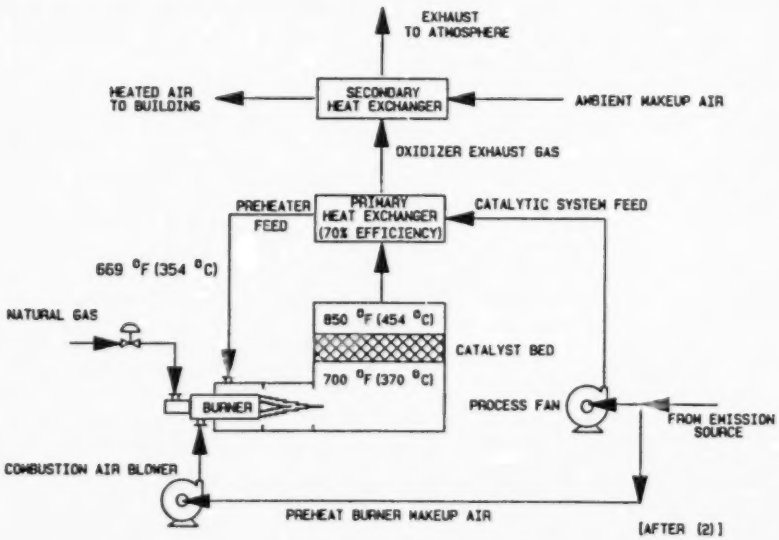

Figure 3. Catalytic oxidation system—typical operating conditions.

ride combustion goes to completion below 700°F (370°C).[14]

The cost of a typical 4,000 scfm (6,800 Nm^3/h) system—including the major items of equipment shown in Figure 3, water and caustic manifolds, controls and control panel, catalyst, and service platforms—is $350,000 to $400,000. The unit, which is preassembled during fabrication, can be installed in the field in approximately seven days at an assembly cost of approximately $25,000. The operating costs of the system are a function of the chlorinated hydrocarbon concentrations and the individual plant operating procedure and can only be calculated based on a specific application.[2]

Summary

Catalytic oxidation is an air pollution control technique whereby VOCs and gas-phase organic air toxics are oxidized at destruction efficiencies of greater than 95 percent. The presence of the catalyst accelerates the rate of oxidation at a given temperature. This allows combustion at lower temperatures than are possible in thermal incinerators. Catalysts can be either noble or non-noble metals deposited on either pelleted or monolithic supports composed of either ceramic or metal. Fixed and fluidized bed catalyst systems are available. The most important factors affecting performance are operating temperature, space velocity (reciprocal of residence time), contaminant concentration and composition, catalyst properties, and the presence of catalyst poisons or inhibitors in the emissions stream. The economics of catalytic oxidation can generally be enhanced by the use of primary heat recovery to supplement and sometimes replace electric or gas preheating of the emissions stream before it is fed to the catalyst bed. Secondary heat recovery for other process uses can also improve system economics.

Catalytic technology has had limited application to the control of groundwater stripping emissions in the field. The known barriers to its application are the dilute nature of air emissions from strippers, the high humidity content of the air stream, the complex chemical nature of the emissions, the need to control chlorinated compounds, and the presence of catalyst poisons and inhibitors such as hydrogen sulfide, biological organic matter, and mineral salts. Limited data from known installations are available.

The printing and graphic arts industries make extended use of catalytic oxidation for control of their air emissions. Two applications of catalytic technology are discussed. In both cases, the vendor claims high destruction efficiency (greater than 95 percent) at moderate inlet temperatures [700°F (370°C)] due to the ease of combusting the emissions. Both vendors identify the presence of phosphorus, silicone, sulfur, and halogens in the exhaust stream as potential inhibitors of catalyst effectiveness. The supplier of the granular fixed-bed noble metal on alumina catalyst system is concerned primarily about masking from phosphorus and silicone, and about deactivation from the halogens. The supplier of the fluidized bed non-noble metal oxide catalyst recognizes the potential for masking, but is not concerned since the surface of their catalyst pellet is believed to be continually cleaned in the fluidized bed. In addition, they are apparently not concerned about the deactivation of non-noble metal catalysts by halogens. Several causes of low destruction efficiency other than catalyst deactivation are identified: low operating temperatures and catalyst levels, and the bypassing of the catalytic unit via cracked heat exchangers and leaking bypass dampers.

One vendor has provided information about the use of a fluidized bed metal oxide catalyst system for destruction of chlorinated hydrocarbon emissions at five sites. They claim a very high destruction efficiency (greater than 99 percent) at moderate temperatures [700°F (370°C)]. Of particular interest in this application is the high variability of organic emission rates and the need to add dilution air to the emission stream to avoid overheating of the catalyst bed. The need for scrubbing of HCl from the catalytic incinerator exhaust is also of note.

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Table IV. Operating conditions for catalytic control of latex monomer production emissions.[2]

Chlorinated HC gas flow	50 to 335 scfm	85 to 570 Nm^3/h
Inlet temperature	700°F	370°C
Heat content	4.4 to 225 Btu/scf	39 to 2,000 kcal/Nm^3
Fuel gas consumption	0.9 to 3.0 scfm	1.5 to 5.1 Nm^3/h
Dilution air flow	60 to 3,000 scfm	100 to 5,100 Nm^3/h
Cooling water rate	110 to 1,000 gph	415 to 3,800 L/h
Caustic addition rate	0 to 150 gph	0 to 750 L/h
Water & caustic to drain	65 to 750 gph	250 to 2,850 L/h
Stack temperature	95 to 160°F	35 to 70°C
Conversion efficiency	99.999%	

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